Halon replacement : analysis of breakdown products

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Abstract

The extinguishing agent used in handheld extinguishers installed on board transport category aircraft must be non toxic to occupants.
The aim of this work is to propose a test method to evaluate the toxicity of the gases produced by the discharge of an extinguishing agent on a seat cushion fire. The tests were carried out in a 8 m^3 chamber designed as a compromise between a realistic volume suitable to the use of a full scale extinguishing system and an efficient sampling of the breakdown products.
At first, toxicity measurements have been conducted on Halon 1211(CF_2ClBr) to be used as a baseline. Then, alternative agents such as FM200 and FE36 have been tested in the same conditions of discharge. The results showed that they were not appropriate. Tests must be conducted on agents conditioned and discharged following their current use.
A new program, based on these conclusions is being prepared.

Introduction

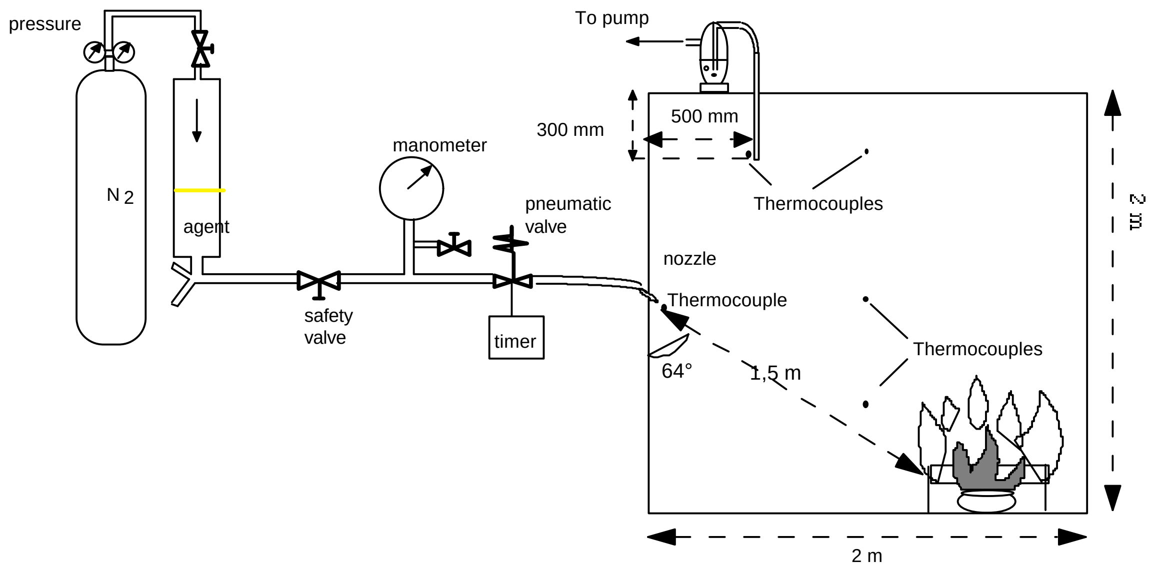
Halons used as extinguishing agents have the capacity to fight fires both in hidden areas and against flammable fluid fires on seat materials. These chemical products belong to the hydrochlorides fluorocarbons(**1**) ($HCFC_S$).
Due to their effect on the increase of the ozone depletion area, the production of these agents ceased in most countries on the first of January 1994. Following this decision, regulatory authorities formed the International Halon Replacement Working Group (IHRWG). In the scope of the IHRWG program, the work conducted at CEAT concerns the toxicity potency of replacement agents. The aim is the comparison between the toxicity of halon 1211 and the toxicity of the available alternative agents.
In this paper, the test equipment developed at the Centre d'Essais Aéronautique de Toulouse will be described, first results and future developments will be presented.

General description of the test rig.

Taking inspiration from the Kidde-UK investigation on hidden fires(**2**), the test chamber was designed as a compromise between a realistic volume for the use of a full scale extinguishing system and an efficient sampling of the breakdown products.
The equipment basically consists of (fig. 1) :

- a 8 m^3 chamber
- a fire source
- a sampling device
- an extinguishing system

The test chamber was located in a ventilated enclosure wich allowed a natural renewal of the test chamber atmosphere every three minutes during the test (**3**) (fire + ventilation).



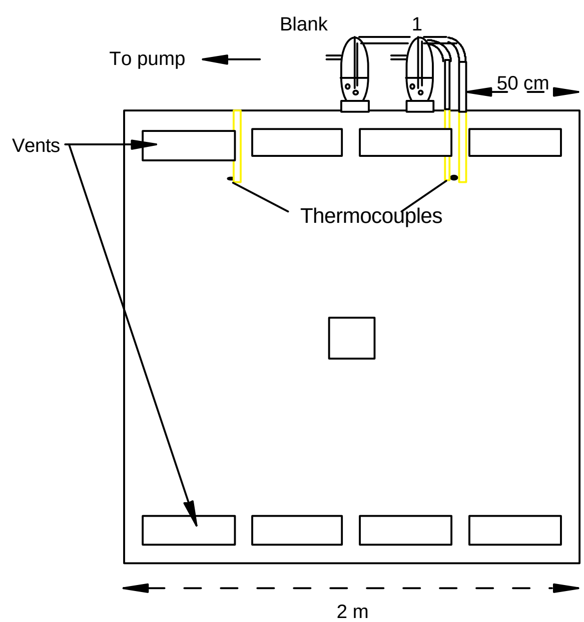
-fig 1-

Test equipment : general view

A great number of modifications has been brought during the preliminary tests both to the equipment and the test protocol, to improve the repeatability of the experiment.
The following description takes all these modifications into account.

Characteristics

Test chamber (fig 2)

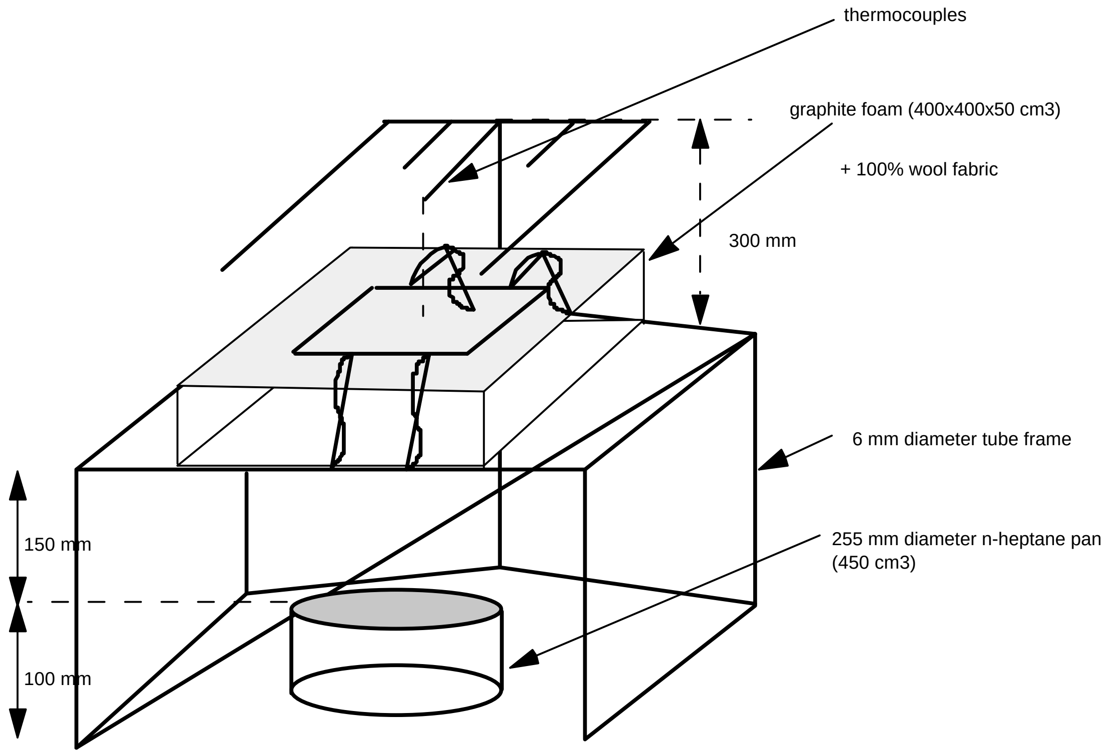


-fig 2-

Halon test chamber : front view

this view shows some details of the test chamber :
Cubic shape : 2 x 2 x 2 m^3
4 vents holes in low position (size 400 x 125 mm^2)
4 vents holes in high position (same size)
Extinguisher attached at the center of the front face.

Fire source (fig 3)



-fig 3-

Seat cushion materials test rig

It was designed as a representative terrorist threat (fuel spread on a seat cushion).
The fuel pan was 255 mm in diameter fuel pan, with an added grid to avoid heptane spread out during the extinction.
The volume of the cushion was 400 x 400 x 50 mm^3 (about one half of standard seat bottom cushion).
The top surface was covered by a 100 % wool fabric.
The foam was a graphite foam which is commonly used on board commercial aircraft.
The test rig was adapted to limit the contact between the extinguishing agent and hot metallic parts. It was built symmetrically over the fire source and materials were placed on a grill made of stainless steel wires.
The total amount of heptane was divided into : 450 cm3 in the pan and 4 times 40 cm3 poured equally on the sample.
The ignition was achieved with an electric igniter.

Position of the fire.

The fire source was placed at the back of the test chamber (fig 1).
The head of the extinguisher was pointed towards the thickness of the sample.
The angle and the distance between the nozzle and the fire source were respectively 65° and 1.5m.

Temperatures measurement

Five K-type thermocouples were employed to check the temperature of the fire above the material, the output being recorded by a data acquisition system. Temperature records are represented on figure 4.

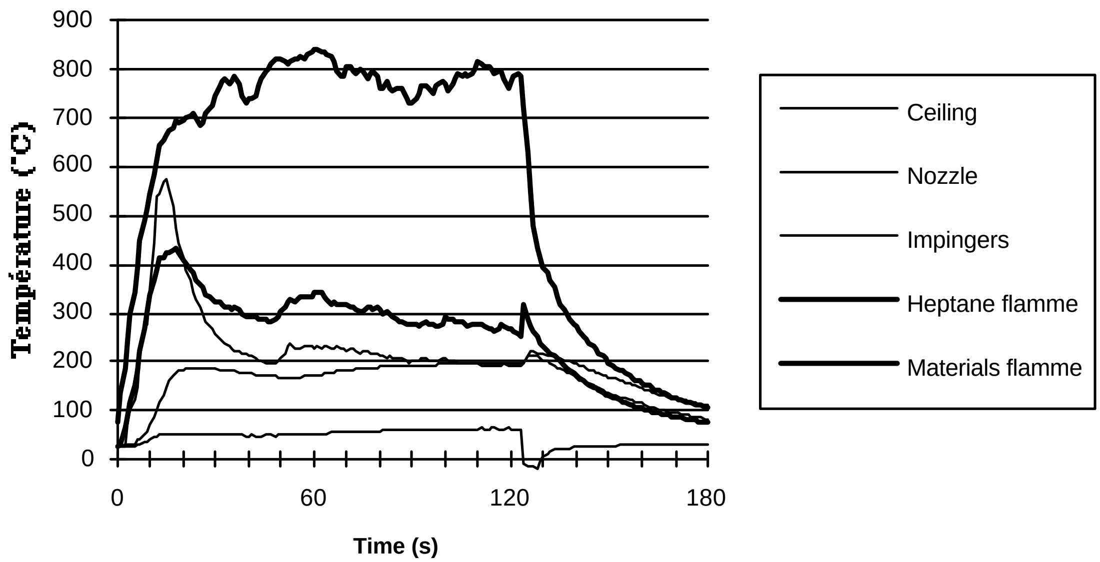


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fig 4-

Characterisation of the cabin materials fire

The heptane flame temperatures on the ceiling over the fire, at the nozzle and at the sampling pipe were also recorded before and during the test.

Extinguishing system

In order to control the time of discharge and the quantity of discharged agent, a special device was built up. A pipe was connected on one end to the bottle and on the other end to the nozzle. The pipe was equipped with a safety ball valve, a pressure gauge and an automatic valve remotely controlled through a timer. A bottle was modified by Kidde-France for discharging agents at constant pressure.

Sampling device

Two impinger bottles for acid gases analysis (HCl, HF, HBr) were placed on the top of the test chamber (1 for blank, 1 for sampling)
Several tests had been conducted earlier(**3**) to find the suitable position of the sampling device : this location is centered in the "by-products cloud" produced at extinction.

Sampling pipes were located on the ceiling, the end beeing at 30 cm from the top inside the test chamber.
Sampling parameters for impinger bottles were : 100ml of distilled water, flow rate 2l/min

Test sequence

- Room temperature must be between 18 to 24°C and relative humidity between 40 and 60%.
- Specimens of foam and fabric must be conditioned to 21 +/- 3°C and 50 +/- 5 % relative humidity for at least 24 hours before test.
- t_o : start up of the test simultaneously with ignition of the fire source.

It takes 2 minutes for stabilization of the materials fire
- t_o + 1 min : blank sampling through impinger bottle, duration 1 minute
- t_o + 2 min : remote -controlled discharge

Simultaneously sampling through the impinger bottle, duration 1 minute.

Test results

Results on halon 1211

Results(**4**) presented on figure 5 were obtained in the following conditions :

Pressure : 14 bars
Time of discharge : 4s
Nozzle diameter : 2,7 mm
Mass loss rate : about 270g/s

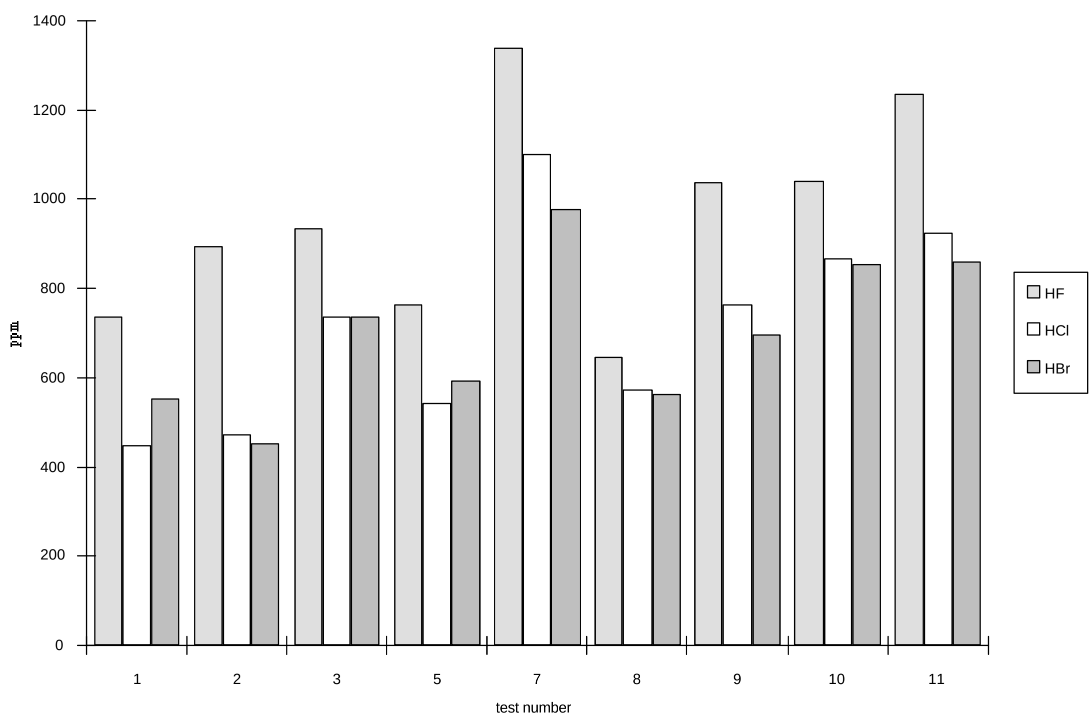


fig 5-

Halon 1211 : HF/HCl/HBr amounts

On a series of 9 tests acid gases level was :

HF : 959 +/- 217 ppm

HC1 : 714+/- 211 ppm

HBr : 698+/-164 ppm

Other tests were carried out at a pressure of 7 bars, 4 seconds of discharge and a smaller nozzle. Results obtained were not repeatable enough to be followed out.

Results on FM200 and FE36 (figure 6)

At first, two alternative agents were available, FM200 (C_3F_7H) and FE36 ($C_3F_6H_2$) wich belong to the halocarbon compounds. Their density is lower than Halon1211. These agents do not contain neither chlorine nor bromine which are involved in ozone depletion. In term of eficiency extinction time is two times higher with FM200 than with Halon 1211, as observed on a carpet fire(**5**).

	FM200				FE 36			
Test number	1	2	3	4	1	2	3	4
Pressure (bars)	14	7	9	9	14	7	9	9
Fire position	back	back	back	back	back	back	back	back
Extinction	no	no	yes	yes	no	no	yes	yes
Test n°/ extinguisher	1	2	3	4	1	2	3	3
HF blank (ppm)	83	37	75	842	141	130	76	512
HF raw (ppm)	40794	31140	19589	36038	41086	6502	11233	34173
HF net (ppm)	40711	31103	19514	35196	40945	6372	11157	33661
Discharge duration (s)	4s	8s	8s	8s	4s	8s	8s	8s
Quantity discharged	3,7 kg for 3 tests				4 kg for 3 tests			
Nozzle diameter (mm)	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7

fig 6-

FM200/FE36 : HF amounts

Four tests were carried out both with FM200 and FE36, the first in the same conditions as halon 1211 :

Pressure : 14 bars

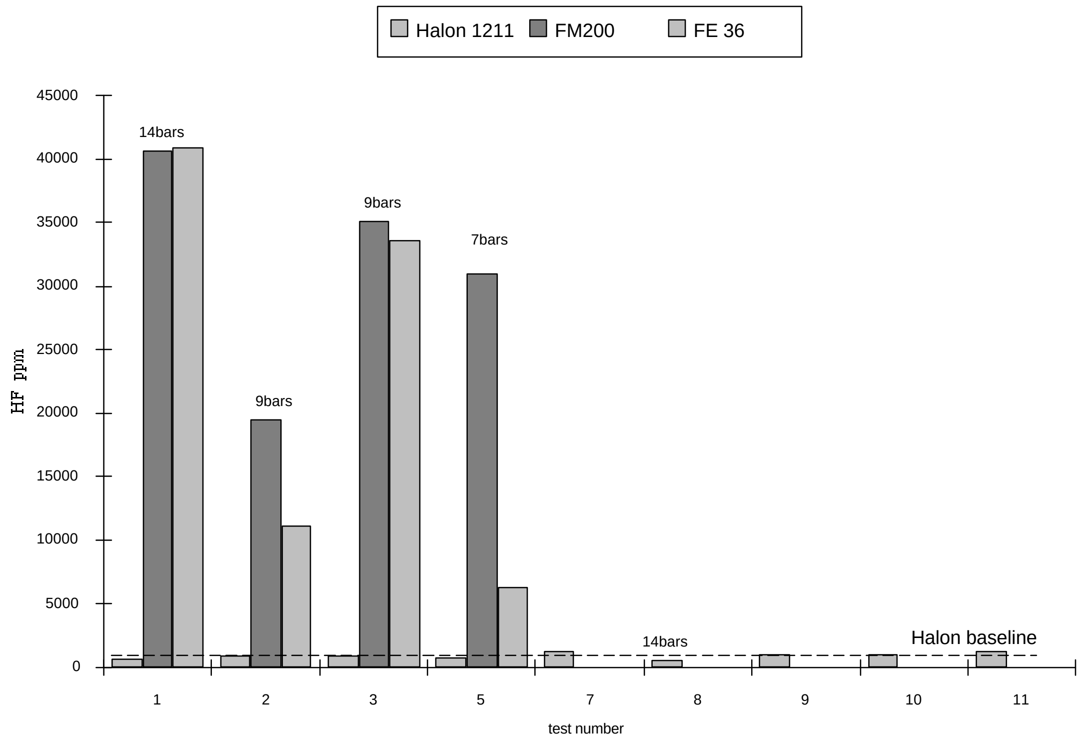
Time of discharge : 4s

Nozzle diameter : 2,7 mm (used with Halon).

Fire was not extinguished and an important “back draft” effect was observed, extinction was only achieved during tests carried out at 9 bars and an 8 second time discharge.

The relative proportion of hydrogen and fluorine atoms in the molecular formula of the agents and water vapour in air (before and during the extinction) influence the amount of HF produced(**1**).

The level of HF remained very high compared to Halon 1211 baseline and showed a great dispersion.



-fig 7-

Comparison between HF rates : H1211/FM200/FE36

Conclusion

The test procedure and test equipment are now suitable for evaluating the amount of toxic gases released by the discharge of an extinguisher.
Results have shown that it is not realistic to compare, in terms of toxicity, FM 200 and FE 36 with the extinguishing system used for Halon 1211.
FM200 and FE36 must be conditioned and discharged with a system adapted to their own physical characteristics. Today no system is available.

Further developments

We are now in the process of defining a new program in cooperation with Kidde-France which aims at testing FM200 and FE36 with an appropriate system of discharge.
The next step will consist in evaluating the Halon 1211 potential toxicity by using the FED model applied to acid gases released during extinction. Afterwards, comparison with alternative agents shall be made.
The system (procedure and equipment) can be applied to any other alternative agent.

References

1- Adam Chattaway, Julian Grigg and David J Spring "Halon Replacement Decomposition Products Studies".

2- Adam Chattaway "The Development of a Hidden Fire Test For Aircraft Hand Extinguisher Applications" CAA/Kidde International, déc 95.

3 - "Etude de la toxicité des produits de dégradation d'agents d'extinction utilisés dans les extincteurs à main des cabines d'avion" Rapport d'essai n°S-95/6527-DGA/CEAT, 1995.

4 - "Définition d'une méthode d'essai pour l'évaluation de la toxicité potentielle d'agents de remplacement du halon utilisés dans les extincteurs à main des cabines d'avion" Rapport d'essai n° S-96/6914- DGA/CEAT, 1996.

5 - K.M.Kallergis "Extinguishing of Aircraft Interior Fires with Halon Replacements for Handheld Extinguishers" DLR Agard-PEP symposium on "Aircraft Fir Safety"-Dresden, Oct 96.